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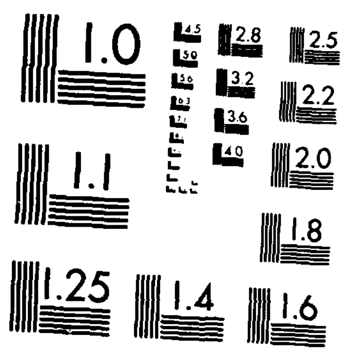

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Estimation and Control of Distributed Models for Certain Elastic Systems Arising in Large Space Structures - AFOSR Grant AFOSR-84-0271

Principal Investigator - Luther W. White

Progress Report - July 1984 - January 1986

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1. Goals of the project.

The goal of this project is to study the estimation and control of elastic systems composed of beams and plates in order to develop efficient and accurate estimation and control algorithms. We have made good progress toward this goal over the last year and a half having obtained results for the estimation in static beams and plates, control and location of actuators for static beams and plates, and identifiability for discrete approximations of second order elliptic boundary value problems. We presently have developed and are currently testing codes for numerical experimentation for estimation of damping and elastic coefficients in dynamic linear plate models, estimation of boundary parameters for second order elliptic problems, estimation of elastic coefficients in cantilevered beams using perturbed boundary conditions, optimal location of actuators for the control of beams, and control of plates through forces at points and forces distributed over sets of small measure and curves.

Our plan over the next year is to investigate boundary control and estimation, estimation and control in structures, use of friction as an active control, and parallelization of estimation and control algorithms.

2. Estimation of parameters.

We have been studying primarily the boundary value problems in 2 dimensions and their one dimensional analogues.

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References

[1] Identifiability under Approximation for Two-Point Boundary Value Problems, with K. Kunisch, to appear *SIAM J. Cont. and Opt.*

[2] Estimation of Elastic Parameters in Beams and Certain Plates: H^1 Regularization, submitted.

[3] Estimation of Elastic Coefficients in Beams: Penalization, submitted.

[4] Shape Control for Static Beams and Plates, submitted.

variety of estimation problems. Moreover, we will proceed to the study of structures to treat various configurations of beams that arise in connection with large space structures. We have begun by considering the deformation of two beams coupled at right angles. In addition, we are interested in the problem of introducing friction as an active control in structures. Finally, we are beginning to study parallel algorithms to apply to estimation and control. This work has been initiated as a collaboration with members of the Parallel Processing Institute at the University of Oklahoma.

In addition to points we have considered control distributed over subsets of Ω of small measure and along curves in Ω. In the functional of (6) we are attempting to fit not only z but its tangents and curvature as well.

Of particular interest in connection with this problem is the following. Given z find a location vector $X = \{x_i \in \Omega : i = 1, \cdots, \omega\}$ such that the control problem (5) gives the best fit. For this problem we consider the solution β of (5) as a function of $X, \beta(X)$. This function is well defined since the control problem (5)-(6) has a unique solution. In addition, we may define a function $X \mapsto j(X) = J(\beta(X))$. We have studied the continuity and differentiability properties of these mappings and have developed an algorithm for the case of a beam to determine the optimal location of an actuator. This work is at the submission stage [4].

In a similar vein we are currently studying similar problems for dynamic models for plates and beams. That is, for plates

$$u_{tt} + A_0 u_t + A_1 u = \sum_{i=1}^{\omega} \beta_i(t)\delta_{x_i} .$$

where A_0 and A_1 are elliptic operators
We have developed a theory for the control of these equations: existence, uniqueness, regularity and approximation and for the determination of optimal actuator locations. Presently, we are coding algorithms for testing in the case of a beam. Our next aim is to study feed back control for these types of problems.

4. Plans for the next year.

We plan to continue our work on beams and paltes and to extend to boundary estimation and control and to nonlinear models. A major desire on our part is to develop a better understanding of the parameter to state mapping for a

Similar techniques may be applied in the case (1) above.

In additional work in estimation we have studied the estimation of elastic coefficients in a cantilevered beam. Here experience as well as discussion with Professors Gary Rosen and Jim Crowley indicate that it is quite difficult to estimate the elastic coefficient near the free end of the beam. By considering perturbations of the free boundary conditions by torsion spring conditions, we have succeeded in obtaining much improved results.

Finally, we have completed codes for the estimation of damping and elastic coefficients for dynamic models of plates. We are currently conducting numerical experiments for these problems. Our analysis will include regularity, approximation, identifiability, and numerical studies.

3. Control.

Thus far, our efforts in control have been directed toward the study of the following problem that is motivated by controlling a deformable mirror. Given Ω (bounded domain in $\mathbb{R}^1$ or $\mathbb{R}^2$), locations $x_i \in \Omega$ for $i = 1,2,\cdots,\omega$, and a desired target deformation $z \in H^2(\Omega)$ with underlying equation (stated for two dimensions)

$$\Delta(a\ u) = \sum_{i=1}^{\omega} \hat{\beta}_i \delta_{x_i} \quad \text{in} \quad \Omega \tag{4}$$

where $a = a(x)$ belongs to $L^{\infty}(\Omega)$ and δ_{x_i} is the Dirac measure with mass at x_i, find $\beta = (\beta_1,\cdots,\beta_\omega) \in \mathbb{R}^{\omega}$ such that

$$J(\beta) = \min_{\hat{\beta} \in \mathbb{R}^{\omega}} J(\hat{\beta}) \tag{5}$$

where

$$J(\hat{\beta}) = \int_{\Omega} a(\Delta(u(\hat{\beta})-z))^2 dx + \varepsilon \sum_{i=1}^{\omega} \beta_i^2 . \tag{6}$$

$$\Delta(a\Delta u) = f \quad \text{in} \quad \Omega \tag{1}$$

$$u_{tt} + \Delta(a_0 \Delta u_t) + \Delta(a_1 \Delta u) = f \quad \text{in} \quad \Omega \times (0,T) \tag{2}$$

accompanied with appropriate boundary conditions clamped, simply supported, cantilevered, etc and initial conditions. Given information z that we view as a member of an observation space Z (Hilbert space), we seek to determine coefficients a, a_0, or a_1 from among a specified subset Q_{ad} of a Hilbert space Q. This is accomplished by means of solving the minimization problem

$$\text{minimize } J(a) = \|u(a) - z\|_Z^2 + \epsilon\|a\|_Q^2 \tag{3}$$
$$\text{subject to } a \in Q_{ad}$$

The set Q_{ad} is specified by constraints that assure the existence of a unique solution to (1) or (2) and to guarantee sufficient compactness to imply the existence of a solution to (3).

To solve these problems numerically one must approximate the boundary value problem by a finite dimensional system and approximate the parameters in some consistent manner. The adaptation of the constraints to the discrete problem is then necessary. We have investigated this for beams and certain plates in [2] and [3] as well as other equations. In these papers regularization and penalization techniques are considered as ways to incorporate constraints. Useful in these analyses is the regularity properties of the estimated parameters. Studies for this problem in the case of a general plate are now being written up. Our work with K. Kunisch has also treated the problem of uniqueness or identifiability for second order equations [1].

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